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REPUBLIC AVIATION CORP., FARMINGDALE, L.I., N.Y.
(REPORT NO. EDR-F905-1)

STRUCTURAL INVESTIGATION OF WING TIP TO WING TIP COUPLING OF F-84 AND B-50 AIRCRAFT

STERN, M. 15 JULY '49 20PP TABLES, DIAGRS

USAF PROJECT MX-1016

AIRPLANES - WING TIP COUPLING
TOWING EQUIPMENT, AERIAL
PROJECT MX-1016

AIRPLANE DESIGN (10)
MILITARY AIRPLANES (11)

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REPUBLIC AVIATION CORPORATION

FARMINGDALE, LONG ISLAND

NEW YORK

A.F. PROJECT MX-1016

Structural Investigation of Wing Tip to Wing Tip Coupling of F-84 and B-50 Aircraft

R.A.C. REPORT EDR-F905-1 7/15/49

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Structural Investigation of

Wing Tip to Wing Tip Coupling of F-84 and B-50 Aircraft

Prepared in Connection with

Phase I of Air Force Project MX-1016

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SUMMARY

A check on the integrity of the F-84E and B-29 wing structures under conditions encountered during wing tip to wing tip coupling was made. The coupling loads used in this analysis were conservative estimates based upon loads computed in the dynamic analysis report. Apart from the replacement of both airplane wing tips, no other structural modifications were assumed in this analysis.

Analyses were made for two types of attachment;

1) locked in pitch and yaw, free in roll.
2) locked in pitch, damped free in yaw, free in roll

Results for the coupled airplanes encountering a 50 foot per second true gust in any direction are given below.

F-84E

Ample margins are maintained for the F-84E under both types of attachment.

B-29

Ample margins on skin shears are maintained for the B-29 under both types of attachment.

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High chordwise bending moments on the B-29 wing result in possible critical combinations of chordwise and beamwise bending moments at Station 699. These result in the following margins of safety:

Attachment 1) M.S. = 0

2) M.S. = 14%

It should be noted that the project calls for the use of a B-50 instead of a B-29 airplane. Although Boeing Stress Reports on the B-50 were not available, it is expected that higher margins can be shown for the B-50.

A third method of attachment has been under consideration in this project:

3) Free in pitch, damped free in yaw, free in roll.

Although the dynamic analysis has not given sufficient data for an estimation of load during this condition, it can be assumed that loads imposed under the more degrees of freedom of this attachment will be lower than those encountered during either of the first two attachments.

INTRODUCTION

This report contains wing structural analyses of an F-84E and a B-29 under conditions encountered during wing tip to wing tip coupling. It is assumed at the outset that both the F-84E and the B-29 wing tips, outboard of their joints (Stations 207 and 819 respectively), will be entirely rebuilt in order to house the attachment mechanism and to provide for load introduction into the wing structures.

The wing structures inboard of these joints are to be considered under three types of attachment;

1) locked in pitch and yaw, free in roll
2) locked in pitch, damped free in yaw, free in roll
3) free in pitch, damped free in yaw, free in roll

Analyses for attachments (1) and (2) are conservative with regard to load estimates made in Report No. EDR-F905-103. Although this report does not give sufficient data for an estimation of load during attachment (3), it can be assumed that loads imposed under the more degrees of freedom of attachment (3) will be lower than those encountered during either of the first two attachments.

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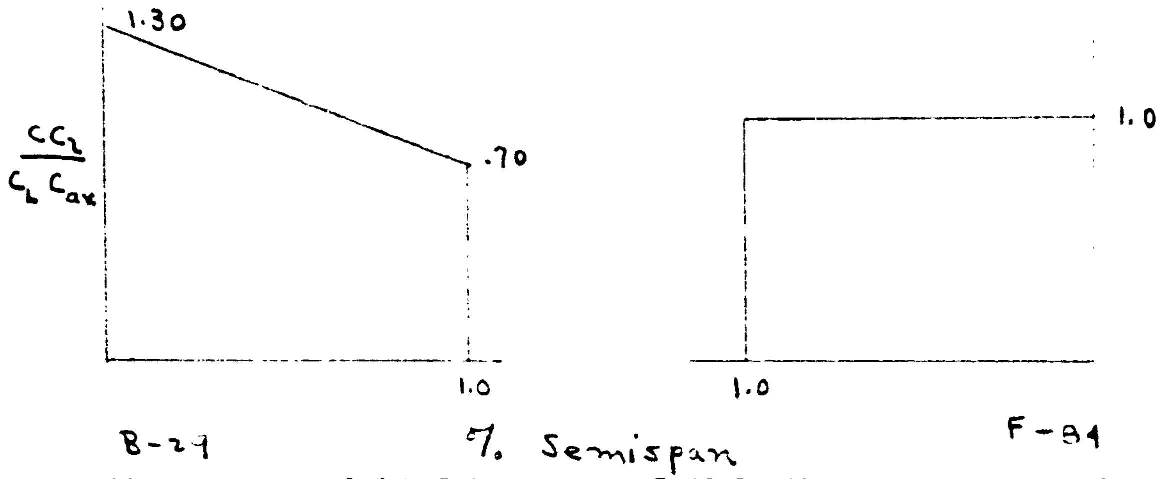
Loads

Reference 1 indicates the following span loadings:



With an effective span of 841.5 inches, the B-29 loading can be expressed as

$$\frac{cc_l}{C_L C_{av.}} = .7 - .000713\ x$$

where x = inches from tip.

The given flight condition corresponds to a limit load factor of 1.2, and an ultimate load factor of n = 1.8

For an assumed 120,000# B-29 and a 14,600# F-84 the air loadings become

$$\text{B-29} \quad w_B = \frac{1.8 \times 120{,}000}{2 \times 841.53} = 128.3\#/\text{in.}$$

$$\text{F-84} \quad w_B = \frac{q\ c c_l\ \alpha}{12} \times n = 35.4 \times 1.8 = 63.7\#/\text{in.}$$

Note: For the B-29, the wing chord coefficient and the design chord load factor were conservatively assumed to be zero.

The wing dead weight distributions are taken from references 2 and 3. This data is sufficient for the computation of air load and dead weight wing beam bending moments shown in Tables I and II.

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TABLE I

B-29 — AIR LOAD & DEAD WEIGHT MOMENTS — n = 1.8

1 Sta. y	2 Δy	3 $\frac{w_B}{2} \Delta y$	Air Load 4	5	6 10^{-3} V	7 10^{-6} M_B	Dead Weight 8 10^{-6} M_B	Net 9 10^{-6} M_B
		64.2 x (2)	.000713y	$\frac{cc_\ell}{C_L c_{av.}}$ 1.30 -(4)	$\Sigma[(5)_n + (5)_{n-1}] \times (3)_{n-1}$	$[(6)_n + (6)_{n-1}] \Delta y/2$		(7) + (8)
841.5	23	1476	.600	.700	--	--	--	--
819	72	4620	.584	.716	2.090	.024	--	.024
747	24	1540	.533	.767	8.941	.421	-.018	.403
723	24	1540	.515	.785	11.332	.664	-.032	.632
699	24	1540	.498	.802	13.776	.966	-.046	.920
675	24	1540	.481	.819	16.272	1.326	-.059	1.267
651	24	1540	.464	.836	18.821	1.747	-.082	1.665
627	24	1540	.447	.853	21.422	2.230	-.105	2.125
603	24	1540	.430	.870	22.735	2.760	-.128	2.632
579	24		.413	.887	25.441	3.338		

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TABLE II

F-84		AIR LOAD & DEAD WEIGHT MOMENTS			n = 1.8
	Air	Load		Dead Weight	Net
1	2	3	4	5	6
Sta.	Δ y	10^{-3} V	10^{-6} M_B	10^{-6} M_B	10^{-6} M_B
y		63.7x(2)	$\Sigma\left[(3)_n-(3)_{n-1}\right]\Delta y/2$		
219	12	--		--	--
207	26	.764	.005	--	.005
181	26	2.421	.046	-.007	.039
155	25	4.077	.130	-.021	.109
130	23	5.669	.252	-.044	.208
107		7.130	.399	-.078	.321

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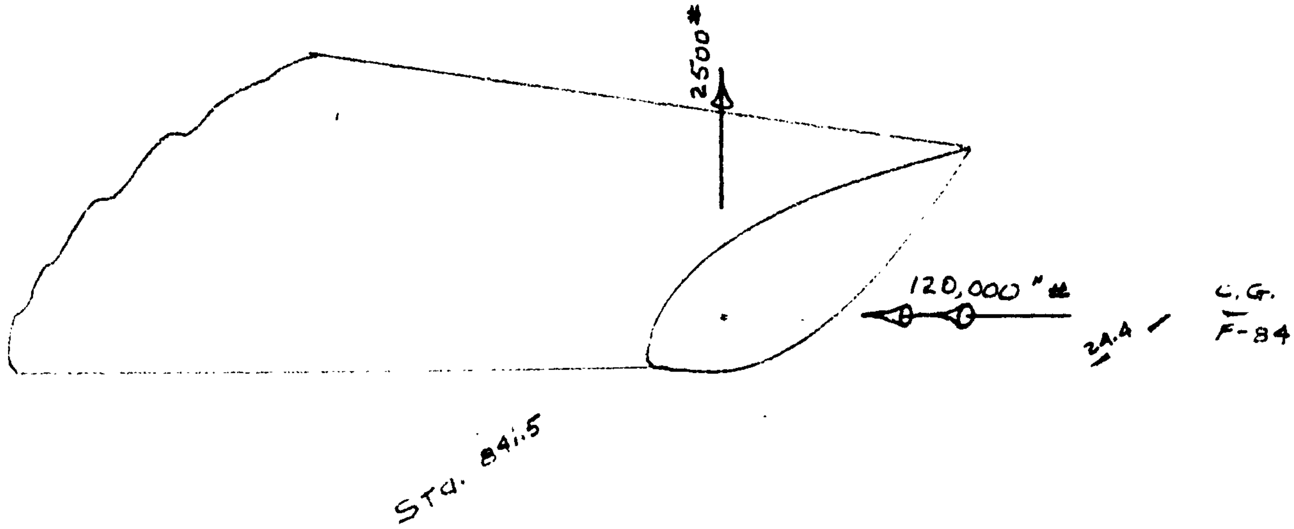
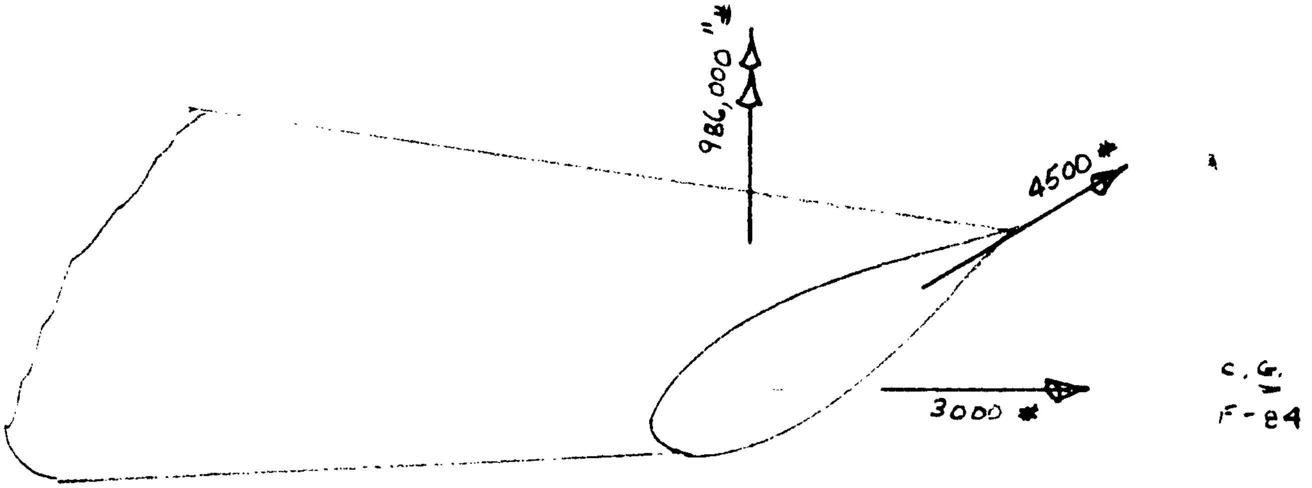
The coupling loads (ultimate) are shown below acting on the B-29 wing tip. These loads are conservative estimates based on data given in Ref. 1.



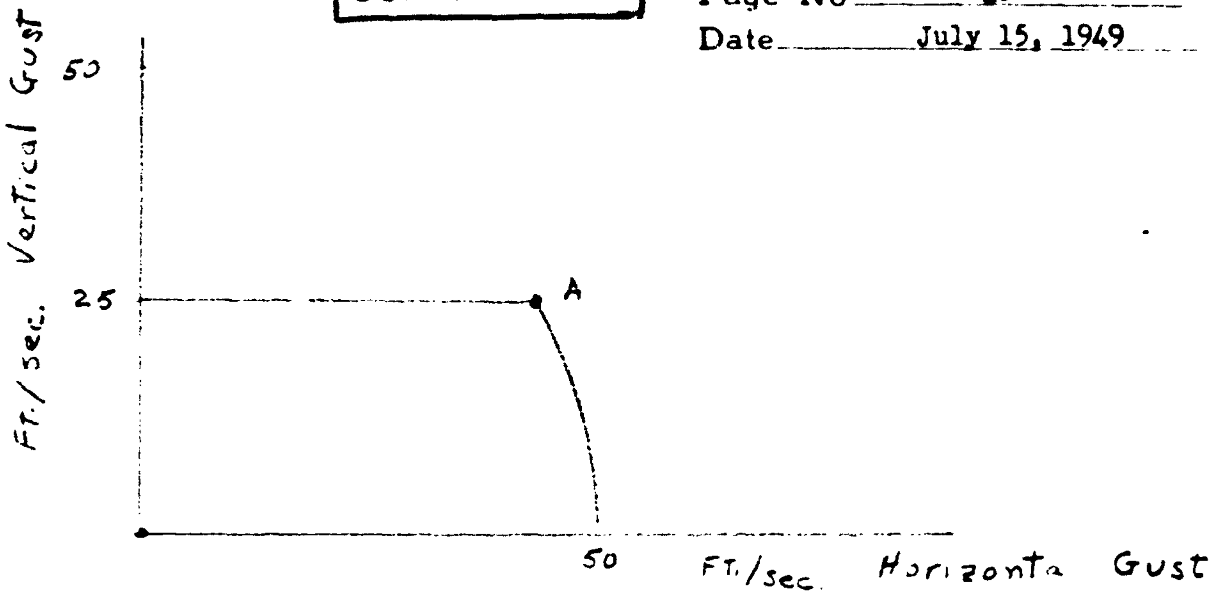
Combined Loads due to Free Roll and Locked Pitch for 25'/sec. vertical gust and 10'/sec. anti-symmetrical gust,



Locked Yaw for 50'/sec. Horizontal Gust

Note: Damped Free Yaw gives 2/3 of the above loads.

It has been assumed that 25'/sec. and 50'/sec. constitute the maximum vertical and horizontal gusts respectively. Since no true resultant gust is expected to exceed 50'/sec., the following resultant gust curve is assumed:



Point A corresponds to a vertical gust of 25'/sec. and a horizontal gust H given by

$$H = 50^2 - 25^2$$

$$= 43.2'/\text{sec.}$$

This combination of vertical and horizontal gusts will be taken as being most critical on the wing structures. It is further assumed that the variation of attachment loads with gust velocity is linear. This results in a factor of .864 to be applied to the previously given horizontal gust loads.

TABLE III

B-29 COUPLING LOAD & NET MOMENTS

Free Roll & Locked Pitch 2500# Tip Load		Net	Locked Yaw 3888# Tip Load	Damped Free Yaw 2592# Tip Load
(1)	(2)	(3)	(4)	(5)
Sta. y	10^{-6} M_B	10^{-6} M_B (2) + $(9)_I$	10^{-6} M_c	10^{-6} M_c .667 x (4)
841.5	---	---	.852	.568
819	.058	.082	.942	.628
747	.238	.641	1.222	.815
723	.298	.930	1.315	.877
699	.358	1.278	1.408	.939
675	.418	1.685	1.502	1.001
651	.478	2.143	1.595	1.063
627	.538	2.663	1.688	1.125
603	.598	3.230	1.782	1.188
579	---	---	---	---

TABLE IV

F-84 COUPLING LOAD & NET MOMENTS

Free Roll & Locked Pitch 2500# Tip Load		Net	* Locked Yaw 4500# Tip Load	Damped Free Yaw * 3888# Tip Load
(1) Sta. y	(2) 10^{-6} M_B	(3) 10^{-6} M_B (2) + $(6)_I$	(4) 10^{-6} M_c	(5) 10^{-6} M_c .864 x (4)
219	---	---	.986	.852
207	.030	.035	.932	.805
181	.095	.134	.815	.704
155	.160	.269	.698	.603
130	.223	.431	.586	.506
107	.280	..601	.482	.416

* **Note**: These loads are more conservative than those used on the B-29. They are based on initial load estimates and have not yet been corrected to the latest data.

Section Properties

B-29 section properties used here are modifications of those appearing in Ref. 2. Since during attachments (1) and (2), high positive chordwise bending moments are applied, the leading edge skin acts in tension and can therefore be taken as fully effective in computing chordwise bending inertia. Although the net effect between chordwise and beamwise bending leaves the leading edge skin in tension, it has been conservatively omitted in the computation of beamwise bending inertias. The beamwise inertias then, are taken directly from the Boeing stress report.

A typical calculation for the modification of chordwise bending inertia is shown for Station 699.

Note: All geometric properties are taken from Ref. 2 .

Nose skin area = 1.12 sq. in. @ $x = 5.5''$

$$\bar{x} = \frac{263.3 + 1.12 \times 5.5}{8.45 + 1.12} = 28.2$$

$$I_y = 1467 + 8.45\,(31.2 - 28.2)^2 + 1.12\,(28.2 - 5.5)^2 = 2120$$

$$I_x = 315$$

$$I_{xy} = 27$$

$$C_1 = \frac{1}{\left(\frac{I_x}{1000}\right)\left(\frac{I_y}{1000}\right) - \left(\frac{I_{xy}}{1000}\right)^2} = 1.500$$

$$C_2 = I_{xy}\,C_1 = 40.5$$

$$C_3 = I_x\,C_1 = 473$$

$$C_4 = I_y\,C_1 = 3180$$

TABLE V

B-29 SECTION PROPERTIES

(1) Sta.	(2) I_{xy}	(3) I_x	(4) I_y	(5) C_1	(6) C_2 (2)x(5)	(7) C_3 (3)x(5)	(8) C_4 (4)x(5)	Rear Spar Upper Cap (9) x	(10) y
819	9.66	29.4	576	59.4	573.6	1746	34200	13.7	4.3
747	29	177	1477	3.81	111	675	5630	20.0	6.1
723	0	240	1789	2.33	0	559	4167	21.5	5.6
699	27	315	2120	1.50	40.5	473	3180	23.0	5.9
675	60	472	2928	.726	43.5	342	2125	23.0	5.9
651	- 8	618	3698	.4376	0	267	1618	24.7	5.8
627	81	843	5260	.2258	18.3	190	1188	26.1	6.5

The F-84E Section Properties were calculated based on Ref. 3.

TABLE VI

F-84 SECTION PROPERTIES

(1) Sta.	(2) I_{xy}	(3) I_x	(4) I_y	(5) C_1	(6) C_2 (2)x(5)	(7) C_3 (3)x(5)	(8) C_4 (4) x (5)	Rear Spar Upper Cap (9) x	(10) y
207	-26.3	23.9	648	67.59	-17777.6	1615.4	43798	18.8	3.50
181	- .7	55.4	1180.7	15.29	- 10.7	847.1	18053	17.0	4.10
155	+87.9	95.6	1382.2	8.04	706.7	768.6	11113	18.1	3.63
130	22.3	112.3	1703.5	5.24	116.9	588.5	8926	19.5	4.31

Allowables

The critical items on both airplanes was found to be the upper cap of the ~~rear spar~~ stringer adj. to rear spar. The column allowable used for the B-29 was based on ANC-5 for a 24-ST extrusion with an end fixity of C = 1.5. This resulted in an allowable of f = -37,500 p.s.i. 36.

For the F-84, the allowable was taken as -55,000 p.s.i. based on Reference 3.

Tables VII and VIII show the combined bending stresses and margins of safety.

TABLE VII

B-29 COMBINED STRESSES IN REAR SPAR UPPER CAP

	Locked Yaw				Damped Free Yaw			
(1) Sta.	(2) K_1 $[C_2M_B - C_3M_C]$ $\times 10^{-6}$	(3) K_2 $[C_4M_B - C_2M_C]$ $\times 10^{-6}$	(4) $K_1 x - K_2 y$	(5) M.S.	(6) K_1 $[C_2M_B - C_3M_C]$ $\times 10^{-6}$	(7) K_2 $[C_4M_B - C_2M_C]$ $\times 10^{-6}$	(8) $K_1 x$ $K_2 y$	(9) M.S.
819	-1598	2264	-31600	.19	-1049	2445	-24900	.51
747	- 764	3473	-36300	.03	- 479	3518	-31000	.21
723	- 735	3875	-37500	0	- 490	3875	-32200	.16
699	- 614	4007	-37700	[illegible]	- 392	4026	-32800	.14
675	- 440	3515	-30800	.22	- 269	3537	-27100	.38
651	- 426	3467	-30600	.23	- 284	3467	-27100	.38
627	- 272	3133	-27500	.36	- 165	3143	-24700	.52

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TABLE VIII

F-84 COMBINED STRESSES IN REAR SPAR UPPER CAP

	Locked Yaw				Damped Free Yaw			
(1) Sta.	(2) K_1 $[C_2M_B - C_3M_C]$ $x10^{-6}$	(3) K_2 $[C_4M_B - C_2M_C]$ $x10^{-6}$	(4) $K_1 x - K_2 y$	(5) M.S. *	(6) K_1 $[C_2M_B - C_3 M_C]$ $x10^{-6}$	(7) K_2 $[C_4M_B - C_2M_C]$ $x10^{-6}$	(8) $K_1 x - K_2 y$	(9) M.S. *
207	-1568	3190	-40600	.35	-1363	2964	-36000	.53
181	-692	2428	-21700	ample	- 598	2427	-20100	ample
155	-346	2496	-15300	ample	- 273	2563	-14200	ample
130	-294	3779	-22000	ample	- 247	3788	-21100	ample

*See Note page 12

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Torsion

The air loading on the B-29 wing is given with pitching moment about the quarter chord equal to zero. The quarter chord of the B-29 wing lies very close to the wing elastic axis. The direct air load torsion introduced is very small therefore.

In addition, the coupling torque is 120,000 in. lbs. The box area at Station 819 may be extrapolated from that of Station 747 (given in Ref. 2) by multiplying by the ratio of chords and thickness ratios. This becomes

$$2A_{819} = 762 \times \frac{37.3}{45.8} \times \frac{9.5}{10.6} = 556 \text{ sq. in.}$$

This results in a shear flow

$$q = \frac{T}{2A} = \frac{120,000}{556} = 215 \text{ \#/in.}$$

This is a relatively small figure and can be combined safely with the acting flexural shear.

The F-84E is designed to carry a 220,000 in. lbs. tip torque about the elastic axis (40% C). This condition occurs at + L.A.A., full tip tanks. (Ref. 3). About this axis, the coupling condition can at most give

$$120,000 + 2500 \times 13.2 = 153,000 \text{ in. lbs.}$$

The torsion introduced into both airplane wings through rigid coupling in pitch is therefore not critical.

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REFERENCES

1. Republic Report No. EDR-F905-103, "Calculations of Motions and Loads Resulting From Gust Disturbances Acting Upon Aircraft in Coupled Flight."

2. Boeing Report No. D-2876

3. Republic Report No. E28-1C

4. ANC-5

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